Section 5.2 Review

Section Summary

- When a process takes place under conditions of constant pressure, the enthalpy change of a system is equal to the amount of heat gained or heat lost by the system.
- The standard enthalpy of a reaction as written (ΔH_r°) is the enthalpy change for the amount in moles of each reactant and product as determined by the coefficient of the term in the chemical equation.
- A process taking place in a simple calorimeter occurs at constant pressure. Therefore, the amount of heat that is exchanged between the calorimeter and the system is equal to the change in the enthalpy of the system.
- Temperature data from a simple calorimetry experiment can be used to calculate the enthalpy of a chemical reaction.
- The standard enthalpy of combustion (ΔH_{comb}°) of a compound is the enthalpy change that occurs when 1 mol of a compound reacts completely with oxygen under the conditions that the reactants started out at 25°C and 100 kPa of pressure and the products cooled to 25°C and 100 kPa of pressure after the reaction was complete.
- A process taking place in a bomb calorimeter occurs at constant volume but not constant pressure.

Review Questions

1. K/U What is the main characteristic of a calorimeter that allows you to determine the thermal energy change?
2. K/U Why is polystyrene a good material to make a simple calorimeter?
3. T/I A reaction in a calorimeter containing 80.0 g of water at 20.0°C causes the temperature to fall by 1.5°C. What is the thermal energy change of the water?
4. K/U The enthalpy of reaction for a neutralization reaction is to be determined by mixing dilute solutions of an acid and a base in a polystyrene coffee cup. What data must be recorded to complete this activity? What assumptions are made to complete the calorimetric calculations?
5. K/U In solving calorimetry problems, the assumption is usually made that the specific heat capacity of a dilute solution is equal to that of water. This is not a valid assumption for concentrated solutions. Suggest a reason why this assumption would not apply for concentrated solutions.
6. K/U The enthalpy change of a reaction, ΔH_r, that is calculated when a solid dissolves in water is −10.0 kJ/mol. Has the temperature of the water increased or decreased in this process? State a reason for your answer.
7. C You have learned about three types of calorimeters in this section. Use a Venn diagram to communicate the similarities and differences in these types of calorimeters. Include sources of error for each type of calorimeter in your summary.
8. A A chemist mixes 100.00 mL of 0.050 mol/L aqueous potassium hydroxide, KOH(aq), with 100.00 mL of 0.050 mol/L nitric acid, HNO_3(aq). The temperature of the reactants is 21.01°C. The temperature after the reaction is complete is 21.34°C.
   a. Determine the molar enthalpy of neutralization for this reaction.
   b. Write the thermochemical equation and draw an enthalpy diagram for the reaction.
9. C Calorimetry is based upon the first and second laws of thermodynamics. Explain this relationship in a brief paragraph supported by a diagram.
10. K/U A bomb calorimeter is classified as an isolated system because neither mass nor energy is exchanged with the surroundings. What type of system describes a flame calorimeter?
11. T/I A 6.60 g sample of a biscuit is burned in a bomb calorimeter having a heat capacity of 11.6 kJ/°C. After the burning is complete, the temperature has increased by 8.41°C. What amount of thermal energy was released per gram of biscuit?
12. A In order to study a person's energy expenditure and ability to burn different fuels such as carbohydrates or fats, a "whole-room calorimeter" is used. Research this topic and write a brief report that describes the design of the room and the measurements that must be taken.
13. K/U Provide an example of a thermochemical equation for a chemical reaction that requires energy to proceed. In your own words, describe how someone would read the equation.

Practice Problems

21. A pellet of potassium hydroxide, KOH(s), having a mass of 0.648 g, is dissolved in 40.0 mL of water in an insulated cup. The temperature of the water increases from 22.6°C to 27.8°C. What is the molar enthalpy of solution, $\Delta H_{solution}$, for KOH(s)? Assume that the solution has a density and a specific heat capacity equal to that of water.

22. When 5.022 g of sodium hydrogen carbonate, $NaHCO_3(s)$, reacts completely with 80.00 mL of acetic acid, $CH_3COOH(aq)$, the temperature increases from 18.6°C to 28.4°C.

$$CH_3COOH(aq) + NaHCO_3(s) \rightarrow CH_3COONa(aq) + CO_2(g) + H_2O(\ell)$$

Assume that the acid solution has the same density and specific heat capacity as water and that the mass of the final solution is 80.00 g. Calculate the molar enthalpy of reaction, ΔH_r.

23. Sodium reacts violently to form sodium hydroxide when placed in water, as shown in the following equation:

$$2Na(s) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + H_2(g)$$

Determine an experimental value for the molar enthalpy of reaction for sodium given the following data:

mass of sodium, Na(s): 0.37 g

mass of water in calorimeter: 175 g

initial temperature of water: 19.30°C

final temperature of mixture: 25.70°C

24. In a simple calorimeter, 250.0 mL of 0.120 mol/L barium chloride, $BaCl_2(aq)$, is mixed with 150.0 mL of 0.200 mol/L sodium sulfate, $Na_2SO_4(aq)$. A precipitate of barium sulfate, $BaSO_4(s)$, forms. The initial temperature of the two solutions is 20.00°C. After mixing, the final temperature of the solutions is 20.49°C. Calculate the enthalpy of reaction, in kilojoules per mole, of $Na_2SO_4(aq)$. Assume that the solutions have densities and specific heat capacities equivalent to those of water.

$$BaCl_2(aq) + Na_2SO_4(aq) \rightarrow 2NaCl(aq) + BaSO_4(s)$$

25. A neutralization reaction occurs when 100.0 mL of 0.200 mol/L aqueous ammonia, $NH_3(aq)$, and 200.0 mL of 0.200 mol/L hydrochloric acid, HCl(aq), are mixed in an insulated cup.

$$NH_3(aq) + HCl(aq) \rightarrow NH_4Cl(aq) + 53.6\ kJ$$

Assuming that the two solutions have the same density and specific heat capacity as water, what temperature change is expected after mixing?

26. In a simple calorimeter, 150.0 mL of 1.000 mol/L NaOH(aq) is mixed with 150.0 mL of 1.000 mol/L HCl(aq). If both solutions were initially at 25.00°C and after mixing the temperature increased to 30.00°C, what is the enthalpy of reaction as written? Assume that the solutions have a density of 1.000 g/mL and a specific heat capacity of 4.19 J/g·°C.

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(\ell)$$

27. The enthalpy of solution for sodium hydroxide, NaOH(s), is given as −55.0 kJ/mol. A chemist prepares 250.0 mL of a 0.100 mol/L solution of NaOH(aq). Assuming that this solution has the same specific heat capacity and density as water, by how much should the water temperature increase as the NaOH(s) dissolves?

28. A neutralization reaction occurs when 120.00 mL of 0.500 mol/L LiOH and 160.00 mL of 0.375 mol/L $HNO_3(aq)$ are mixed in an insulated cup. Initially, the solutions are at the same temperature. If the highest temperature reached during mixing was 24.5°C, what was the initial temperature of the solutions?

$$LiOH(aq) + HNO_3(aq) \rightarrow LiNO_3(aq) + H_2O(\ell) + 53.1\ kJ$$

Assume that both of these solutions have a density of 1.00 g/mL and a specific heat capacity of 4.19 J/g·°C.

29. Peroxides will react to release oxygen when added to water. By how much would the water temperature change if 7.800 g of sodium peroxide, $Na_2O_2(s)$, is added to 110.00 mL of water?

$$2Na_2O_2(s) + 2H_2O(\ell) \rightarrow 4NaOH(aq) + O_2(g) \qquad \Delta H° = -285.0\ kJ$$

30. In an insulated calorimeter, 200.0 mL of 1.00 mol/L potassium hydroxide, KOH(aq), is mixed with an equal volume of 1.00 mol/L sulfuric acid, $H_2SO_4(aq)$. The temperature increases by 6.50°C. Assume that the solutions have the same density and specific heat capacity as water.

$$H_2SO_4(aq) + 2KOH(aq) \rightarrow K_2SO_4(aq) + 2H_2O(\ell)$$

What is the molar enthalpy of neutralization?